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(54) **VARIABLE EXHAUST MIXER AND COOLER FOR A THREE-STREAM GAS TURBINE ENGINE**

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F02K 1/36 (2006.01)
F02K 1/46 (2006.01)
F02K 1/38 (2006.01)
F02K 3/06 (2006.01)

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See application file for complete search history.

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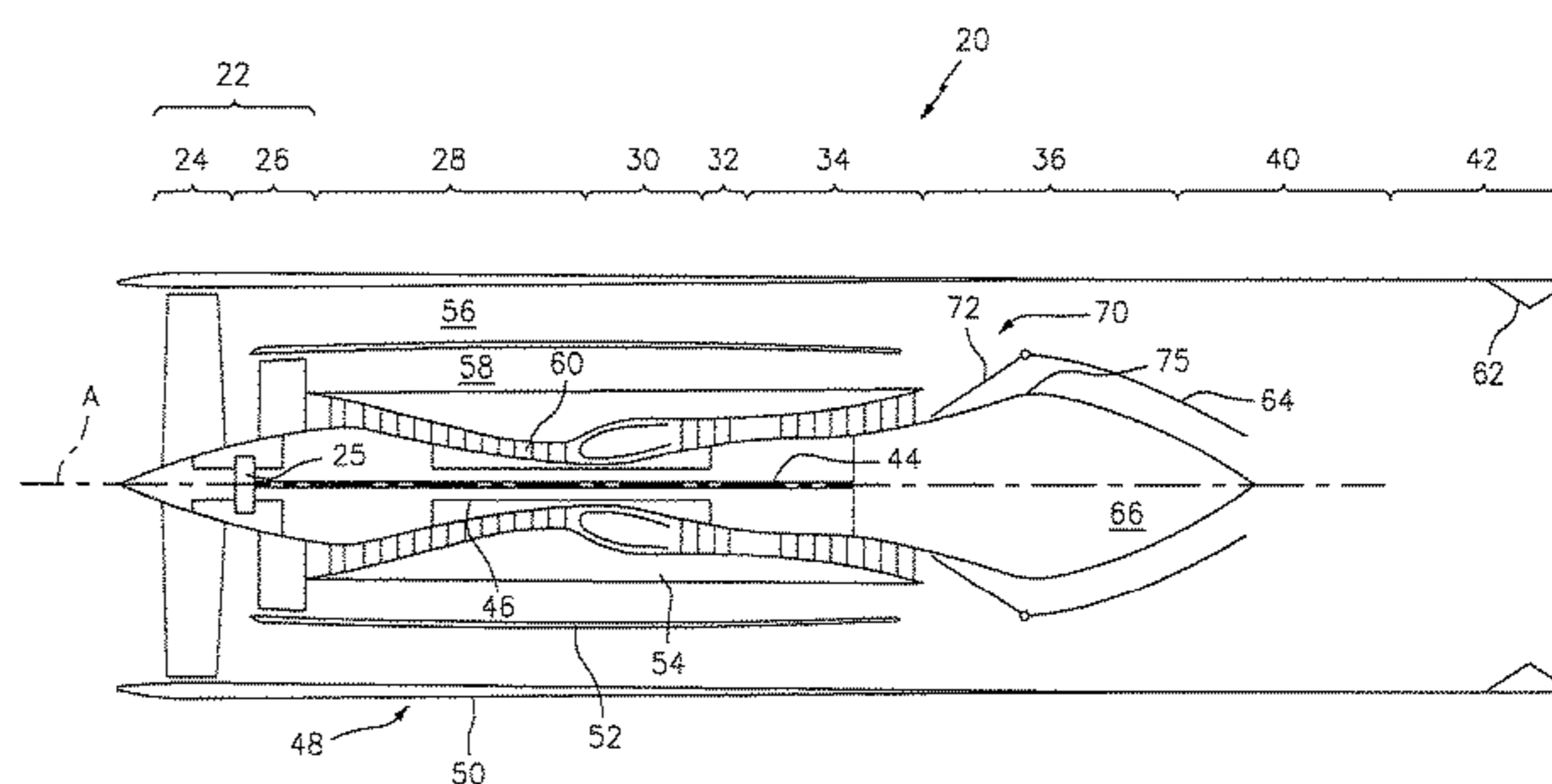
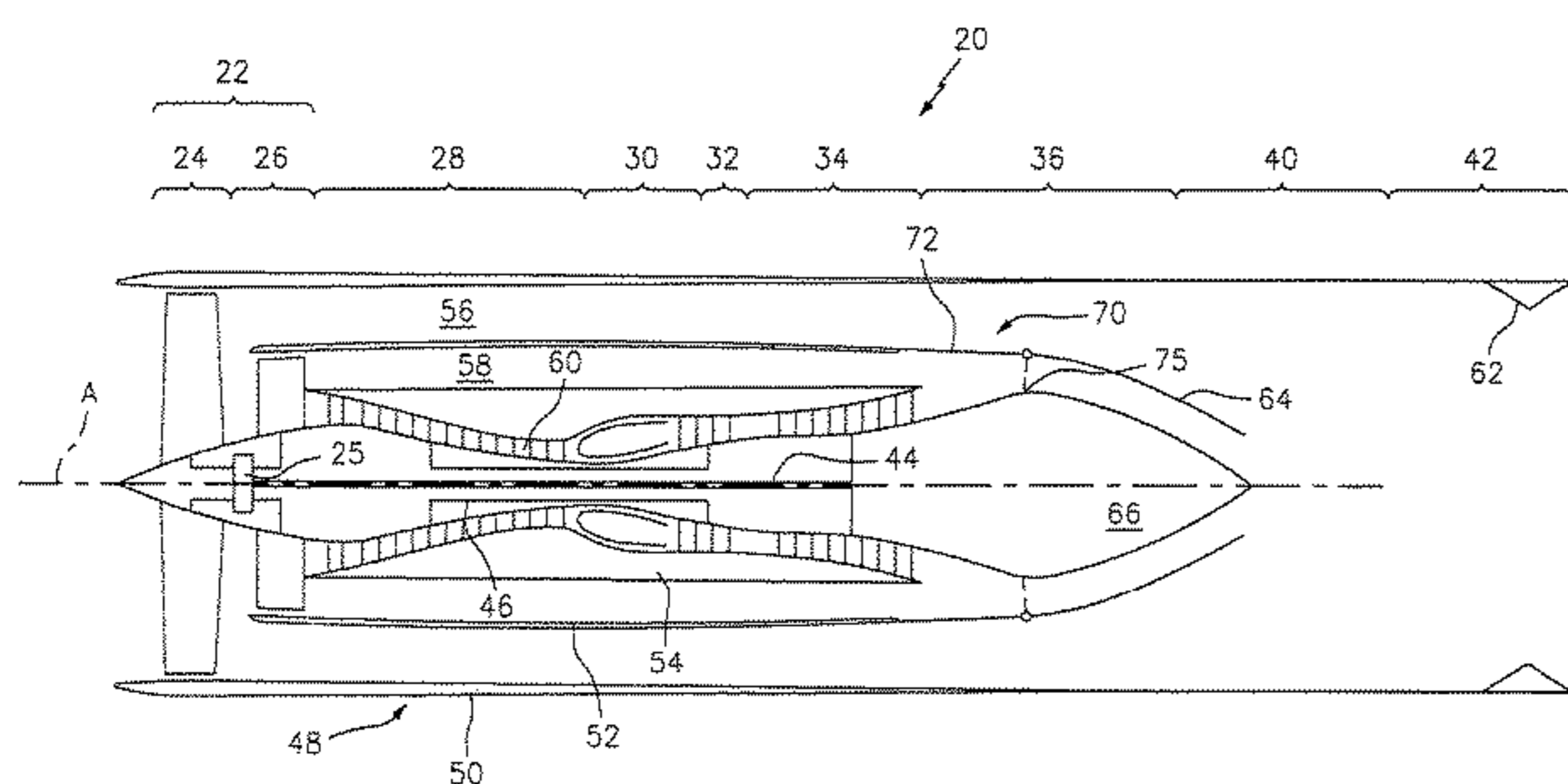
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(57) **ABSTRACT**

A gas turbine engine includes an outer case structure around a central longitudinal engine axis. An intermediate case structure is included inboard of the outer case structure. An inner case structure is included inboard of the intermediate case structure. A variable area exhaust mixer is included, which is movable between a closed position adjacent to the intermediate case structure and an open position adjacent to the inner case structure.

10 Claims, 12 Drawing Sheets



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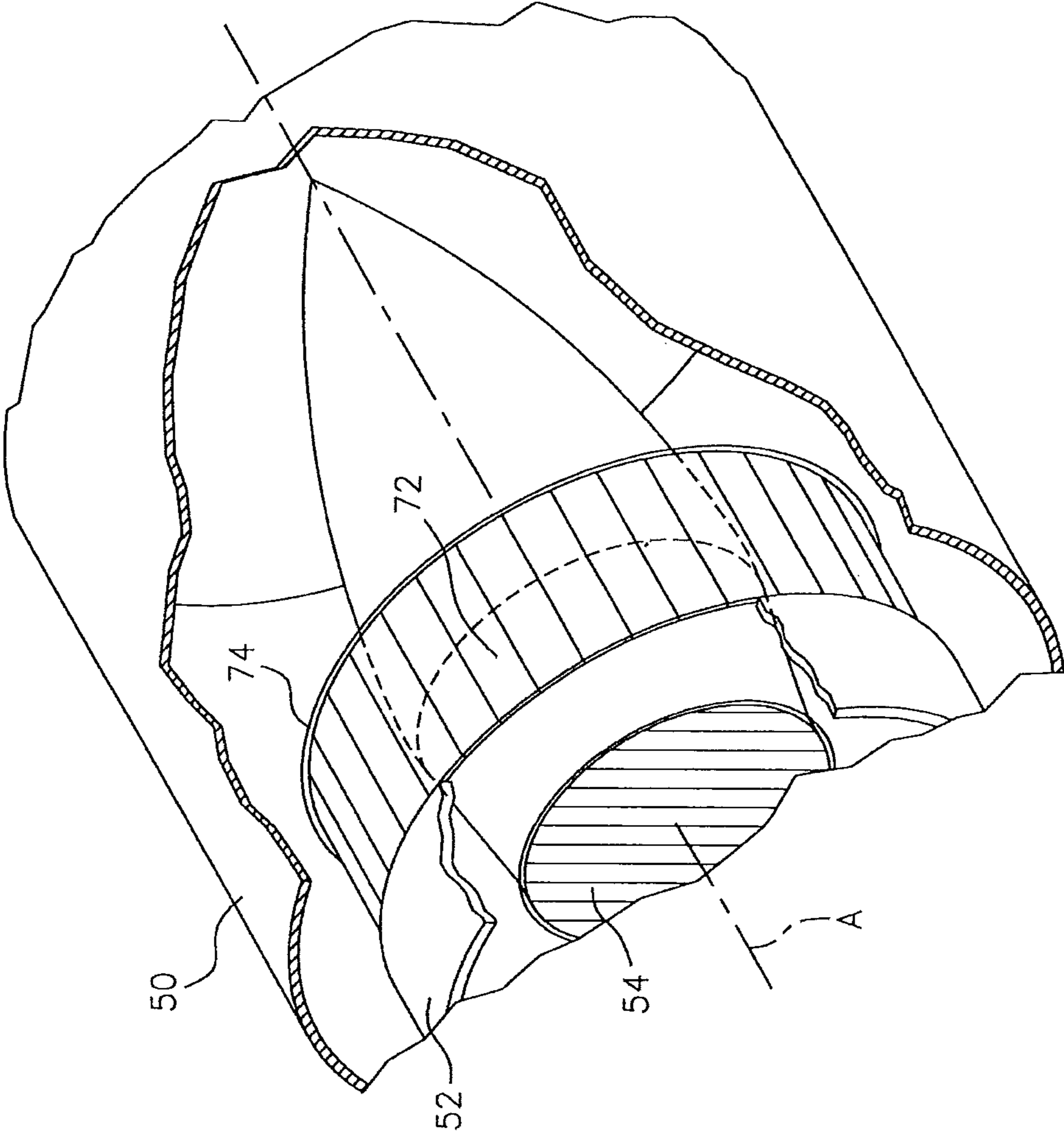


FIG. 2

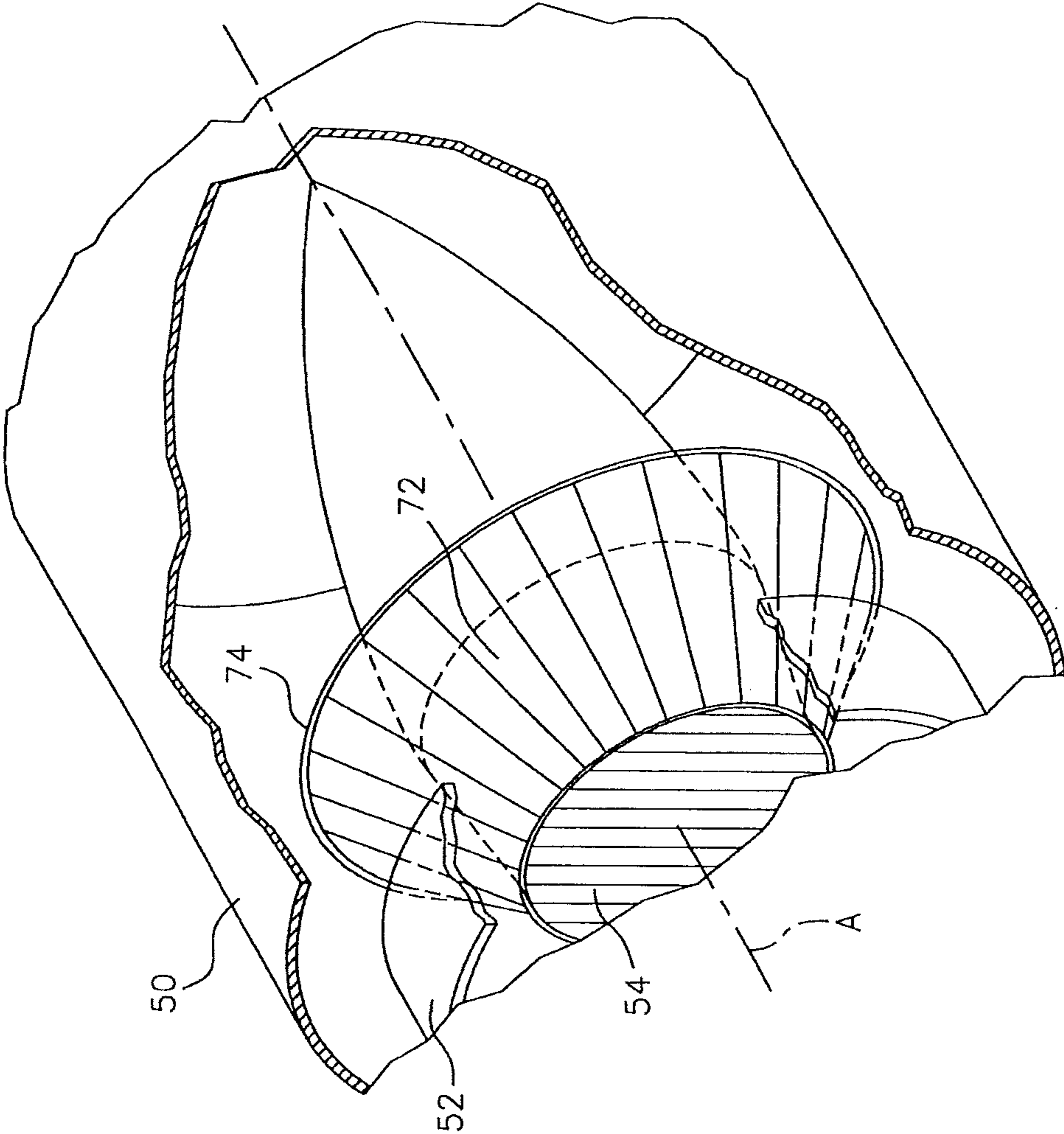


FIG. 3

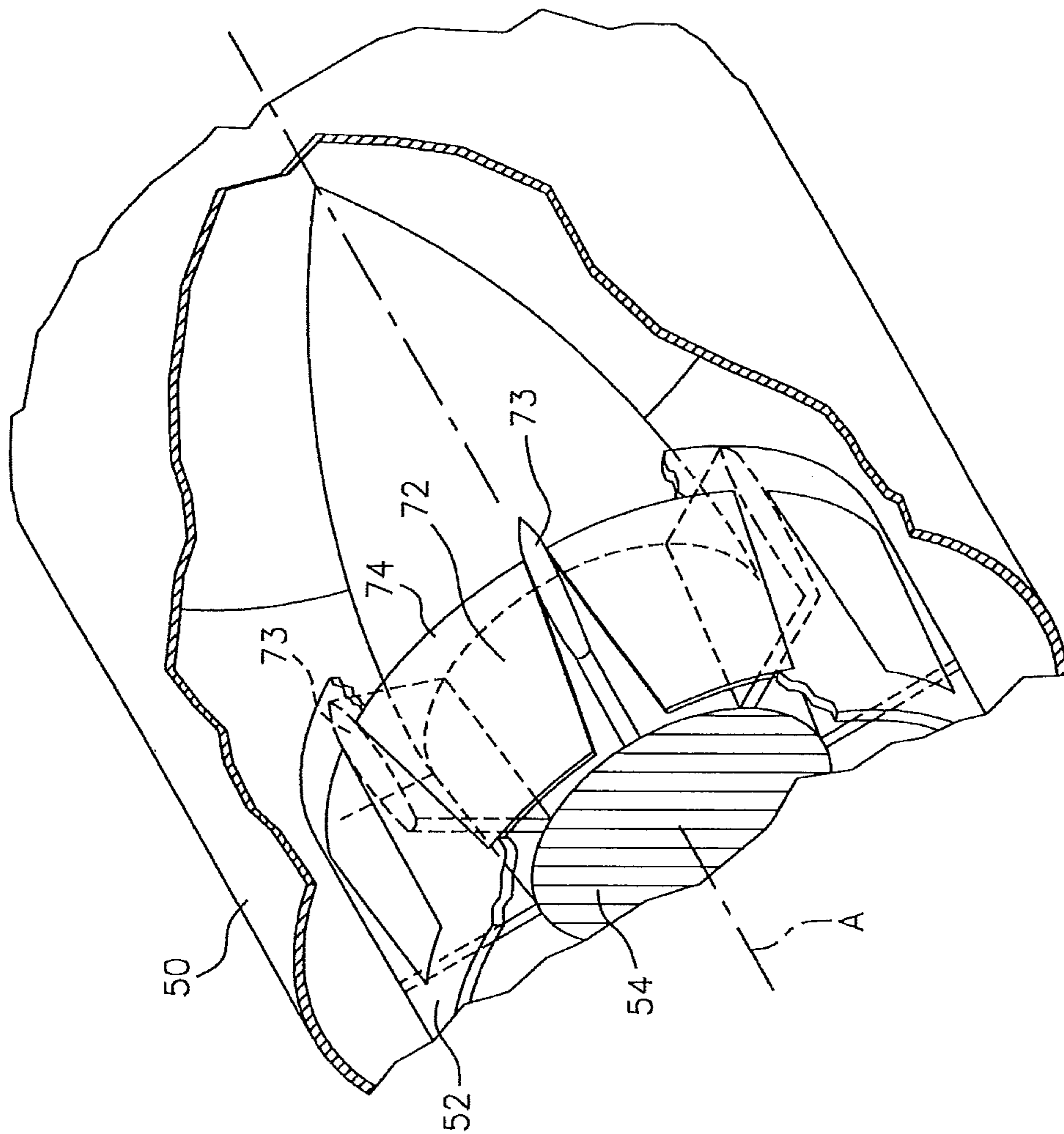


FIG. 4

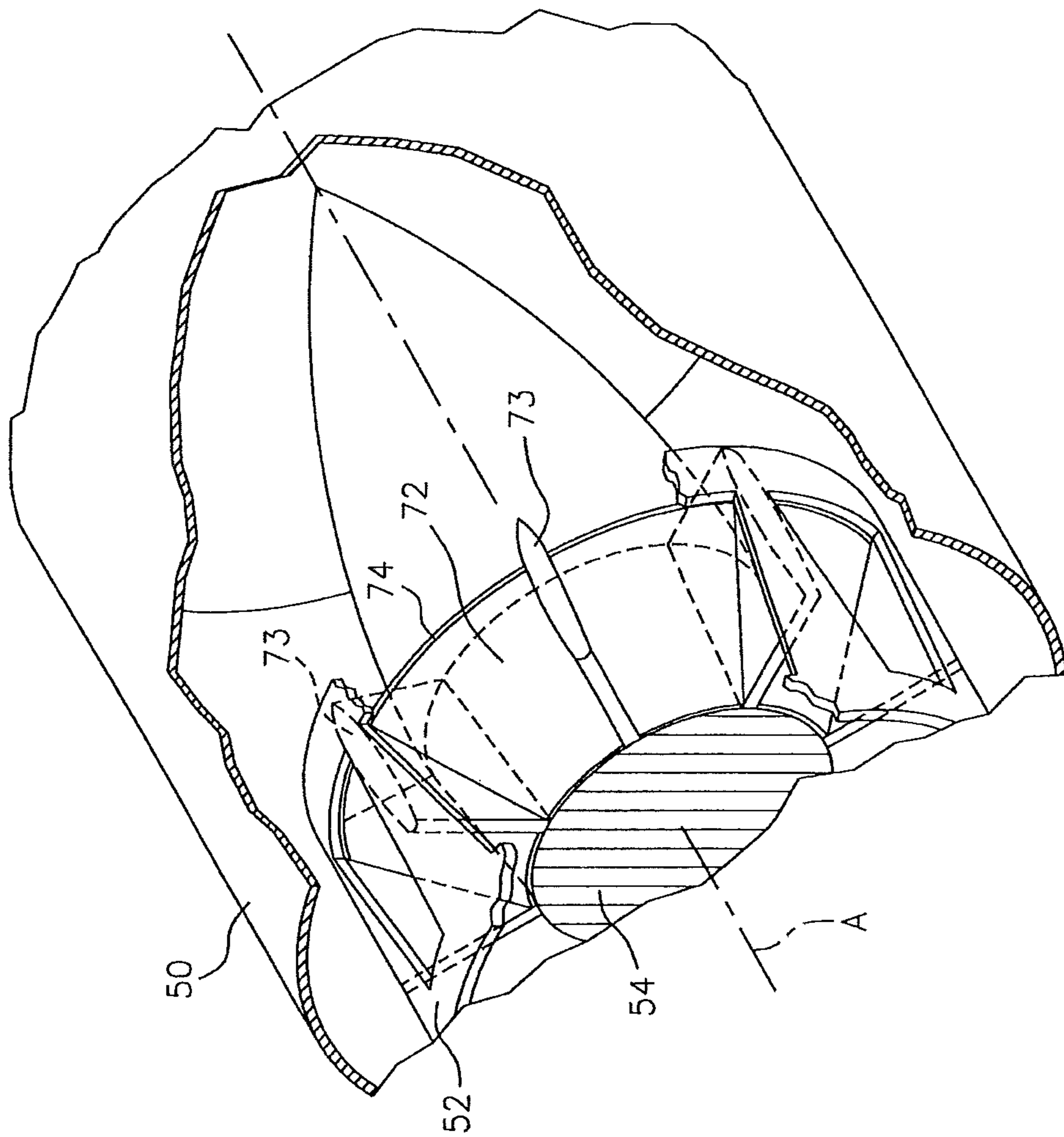


FIG. 5

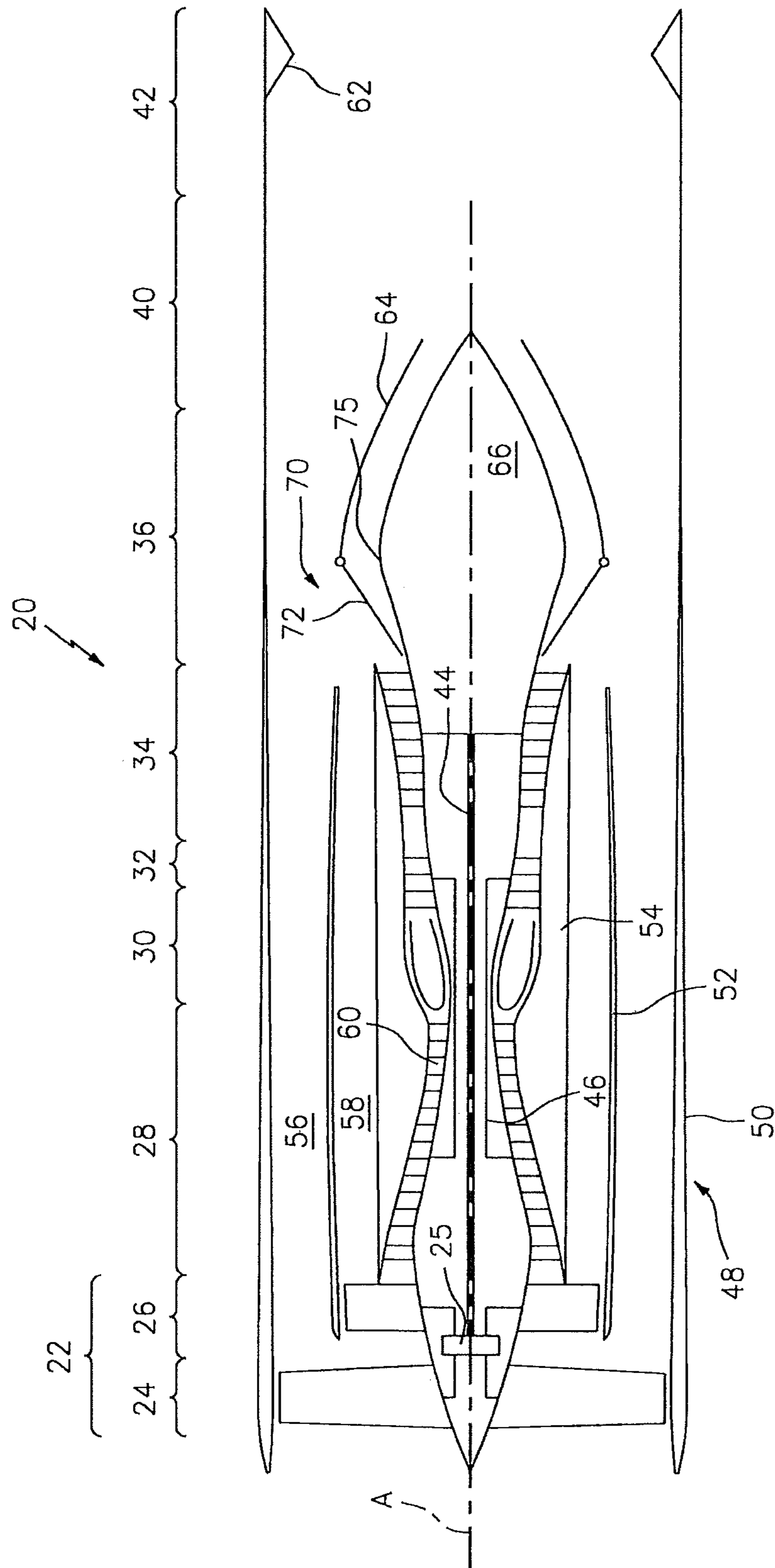


FIG. 6

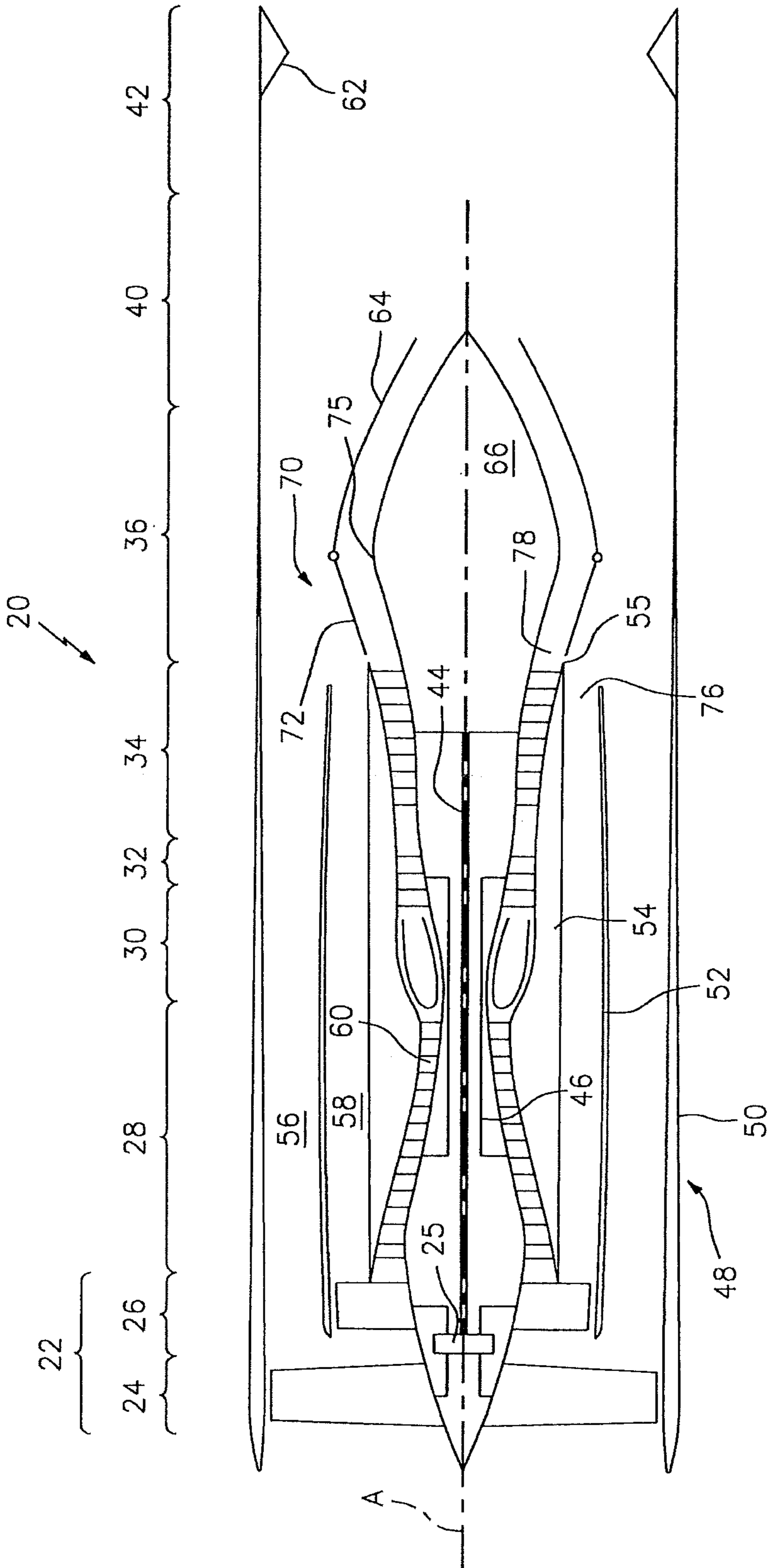


FIG. 7

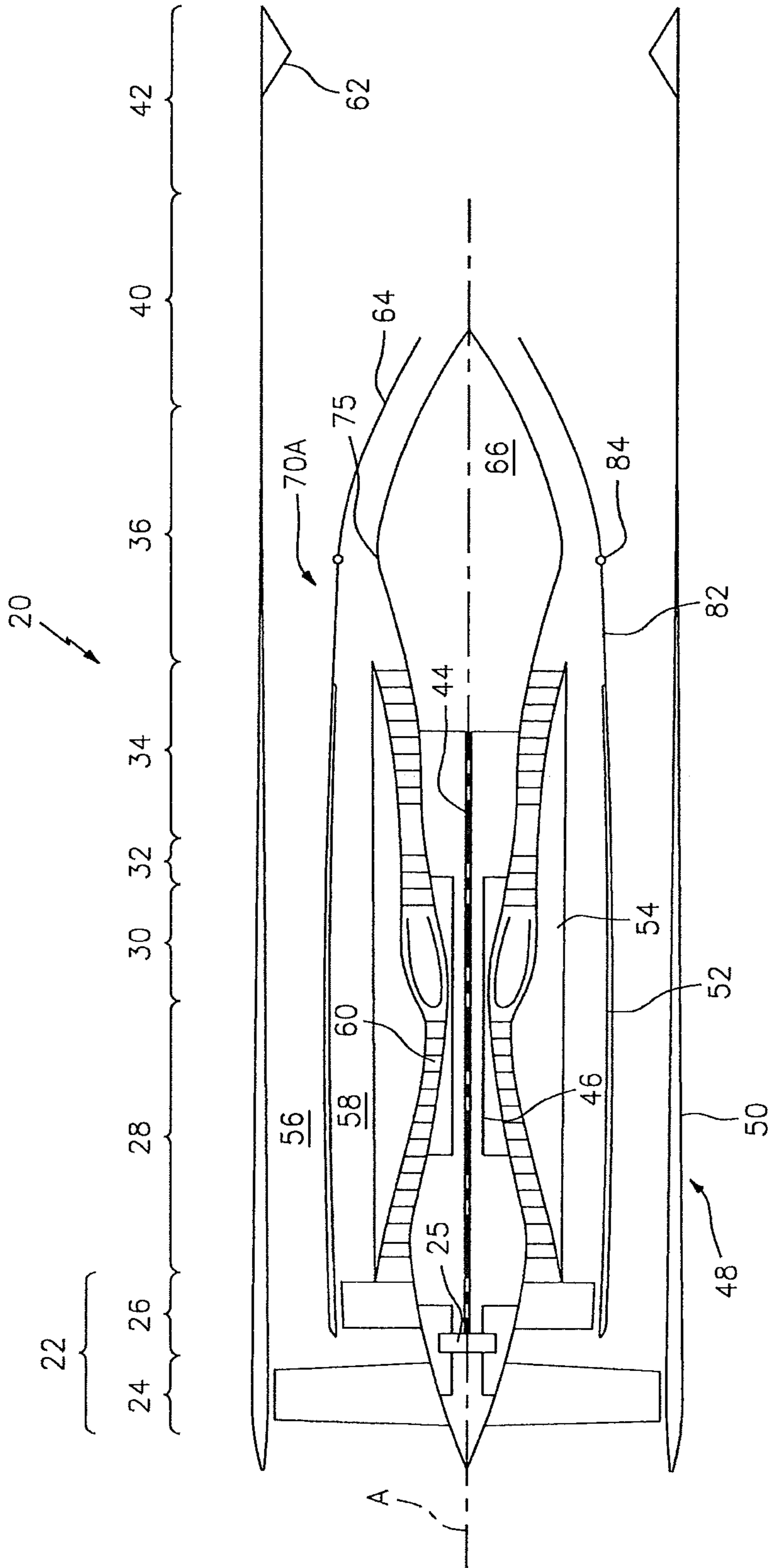


FIG. 8

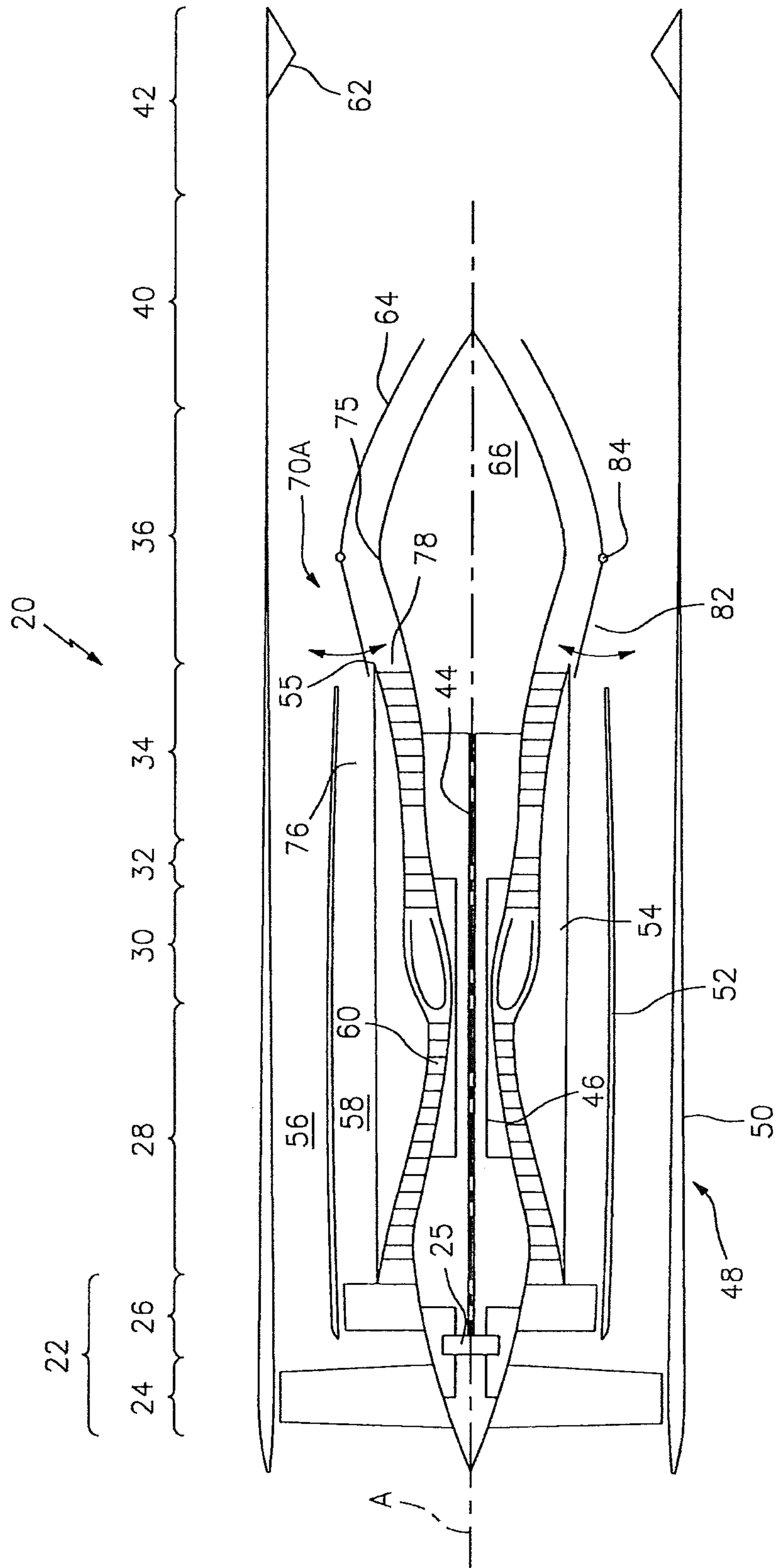


FIG. 9

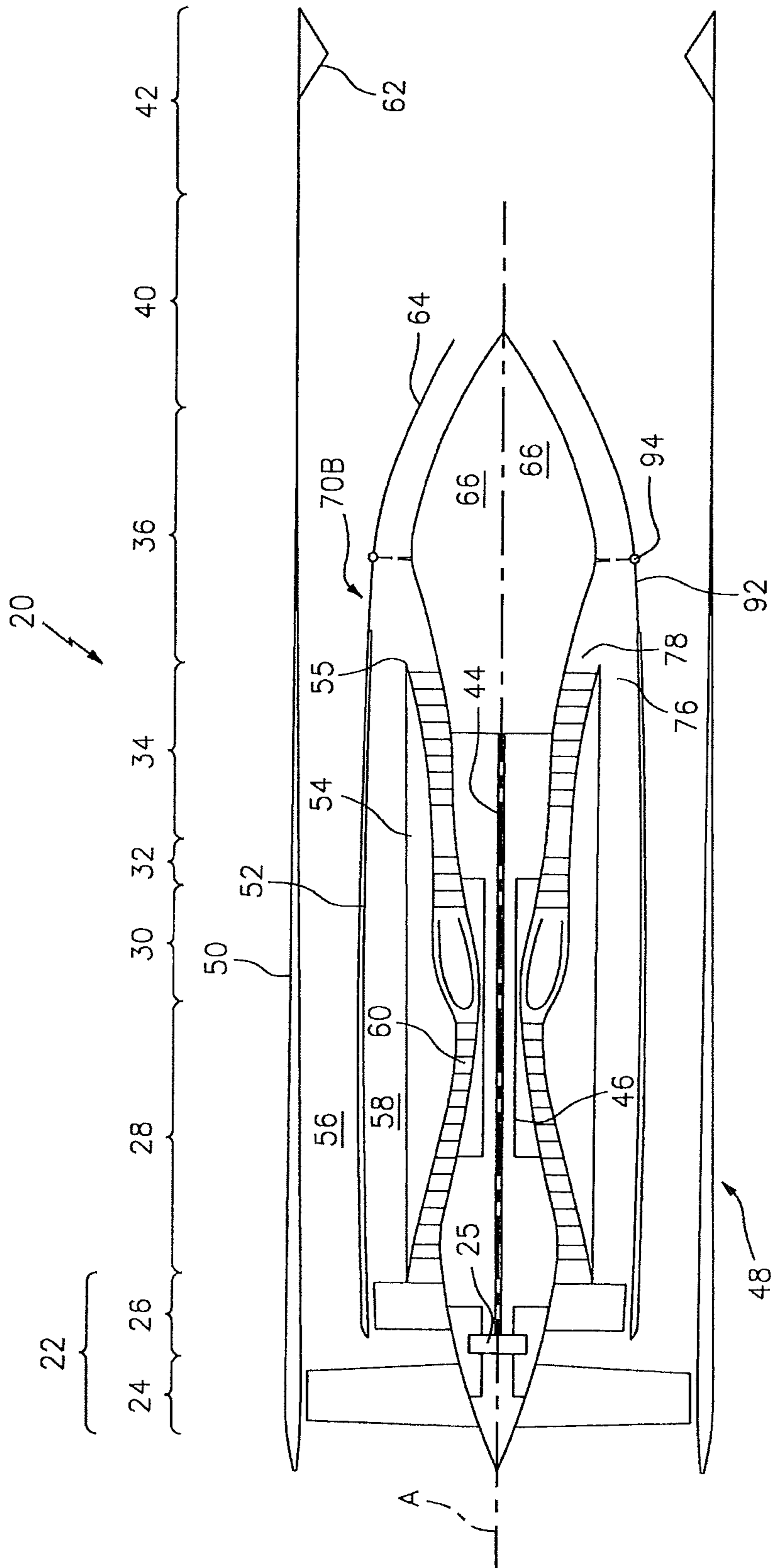


FIG. 10

**VARIABLE EXHAUST MIXER AND COOLER
FOR A THREE-STREAM GAS TURBINE
ENGINE**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 14/553,284 filed Nov. 25, 2014, which claims priority to U.S. Provisional Patent Application Ser. No. 61/931,957 filed Jan. 27, 2014, both of which are hereby incorporated herein by reference in their entireties.

This invention was made with government support under Contract No. FA8650-09-D-2923/DO13 awarded by the United States Air Force. The government may have certain rights in the invention.

BACKGROUND

The present disclosure relates to variable cycle gas turbine engines, and more particularly to an exhaust mixer therefor.

Variable cycle gas turbine engines power aircraft over a range of operating conditions yet achieve countervailing objectives such as high specific thrust and low fuel consumption. The variable cycle gas turbine engine essentially alters its bypass ratio during flight to match requirements. This facilitates efficient performance over a broad range of altitudes and flight conditions to selectively generate high thrust for high-energy maneuvers and optimized fuel efficiency for cruise and loiter.

An exhaust nozzle enhances the thrust produced by the gas turbine engine. In variable cycle gas turbine engines, each flow stream may require a particular nozzle.

SUMMARY

A gas turbine engine, according to one disclosed non-limiting embodiment of the present disclosure, includes an outer case structure around a central longitudinal engine axis. An intermediate case structure is included inboard of the outer case structure. An inner case structure is included inboard of the intermediate case structure. A variable area exhaust mixer is included, which is movable between a closed position adjacent to the intermediate case structure and an open position adjacent to the inner case structure.

In a further embodiment of the present disclosure, the variable area exhaust mixer is downstream of a turbine section.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer includes a hinge axis radially outboard of a maximum outer diameter of a tailcone.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the hinge axis is axially aft of a multiple of respective flaps.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the multiple of respective flaps open radially inward toward the inner case structure.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the multiple of respective flaps are operable to extend toward a wall in the inner case structure, when between the closed position and the open position.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the wall separates an exhaust of a second stream flow path and an exhaust of a core flow path.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the multiple of respective flaps are operable to extend to the wall to segregates the second stream flow path and the core flow path.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer is upstream of a tailcone.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer is upstream of a nozzle section.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the nozzle section includes a convergent/divergent nozzle.

A gas turbine engine, according to another disclosed non-limiting embodiment of the present disclosure, includes a third stream flow path, a second stream flow path inboard of the third stream flow path, a core flow path inboard of the second stream flow path, and a variable area exhaust mixer operable to control flow between the third stream flow path, the second stream flow path and the core flow path.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer is operable to segregate the core flow path in a position between the closed position and the open position.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer is operable to selectively mix a core flow from the core flow path with a bypass flow stream of the third stream flow path and a second flow from the second stream flow path.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer is downstream of a turbine section.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the variable area exhaust mixer includes a hinge axis radially outboard of a maximum outer diameter of a tailcone.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the hinge axis is axially aft of a multiple of respective flaps.

A method of operating a gas turbine engine, according to another disclosed non-limiting embodiment of the present disclosure, includes selectively controlling flow between a third stream flow path, a second stream flow path and a core flow path downstream of turbine section.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the method includes segregating the third stream flow path from the second stream flow path and the core flow path.

In a further embodiment of any of the foregoing embodiments of the present disclosure, the method includes segregating the core flow path from the third stream flow path and the second stream flow path.

The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, the following description and drawings are intended to be exemplary in nature and non-limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Various features will become apparent to those skilled in the art from the following detailed description of the dis-

closed non-limiting embodiment(s). The drawings that accompany the detailed description can be briefly described as follows:

FIG. 1 is a general sectional schematic view of an exemplary variable cycle gas turbine engine with a variable area exhaust mixer according to one disclosed non-limiting embodiment in a closed position;

FIG. 2 is an expanded general schematic view of a variable area exhaust mixer according to one non-limiting embodiment in a closed position;

FIG. 3 is an expanded general schematic view of the variable area exhaust mixer of FIG. 2 in an open position;

FIG. 4 is an expanded general schematic view of a variable area exhaust mixer according to one non-limiting embodiment in a closed position;

FIG. 5 is an expanded general schematic view of the variable area exhaust mixer of FIG. 4 in an open position;

FIG. 6 is a general sectional schematic view of the exemplary variable cycle gas turbine engine of FIG. 1 with the variable area exhaust mixer in an open position;

FIG. 7 is a general sectional schematic view of the exemplary variable cycle gas turbine engine of FIG. 1 with the variable area exhaust mixer in an intermediate position;

FIG. 8 is a general sectional schematic view of an exemplary variable cycle gas turbine engine with a variable area exhaust mixer according to another disclosed non-limiting embodiment in a closed position;

FIG. 9 is a general sectional schematic view of the exemplary variable cycle gas turbine engine of FIG. 8 with the variable area exhaust mixer in an open position;

FIG. 10 is a general sectional schematic view of an exemplary variable cycle gas turbine engine with a variable area exhaust mixer according to another disclosed non-limiting embodiment in a closed position;

FIG. 11 is a general sectional schematic view of the exemplary variable cycle gas turbine engine of FIG. 10 with the variable area exhaust mixer in an intermediate position; and

FIG. 12 is a general sectional schematic view of the exemplary variable cycle gas turbine engine of FIG. 10 with the variable area exhaust mixer in an open position.

DETAILED DESCRIPTION

FIG. 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a variable cycle two-spool bypass turbofan that generally includes: a fan section 22 with a first fan section 24 and a second fan section 26; a high pressure compressor section 28; a combustor section 30; a high pressure turbine section 32; a low pressure turbine section 34; an exhaust duct section 36; an augmentor section 40 and a nozzle section 42. Additional sections, systems and features such as a geared architecture 25 may be located in various engine sections, for example, between the fan sections 24, 26 or aft of the low pressure turbine section 34. The sections are defined along a central longitudinal engine axis A about which a low spool 44 and a high spool 46 rotate relative to an engine case structure 48. Although a particular architecture is disclosed in the various non-limiting embodiment, it should be appreciated that other architectures, such as three-spool architectures, will also benefit herefrom.

The engine case structure 48 generally includes an outer case structure 50, an intermediate case structure 52 and an inner case structure 54. It should be appreciated that various integral or assembled structures, may form the case structure 48 to essentially define an exoskeleton that supports the

spools 44, 46 for rotation therein. A third stream flow path 56 is generally defined by the outer case structure 50 and the intermediate case structure 52. A second stream flow path 58 is generally defined by the intermediate case structure 52 and the inner case structure 54. A core flow path 60 is generally defined by the inner case structure 54. The second stream flow path 58 is defined radially inward of the third stream flow path 56 and the core flow path 60 is radially inward of the second stream flow path 58.

The first fan section 24 communicates the bypass flow stream into a third stream flow path 56, a second stream flow path 58 and a first or primary core flow path 60 that is in communication with the combustor section 30. The second fan section 26 communicates a second flow stream into the second stream flow path 58 and the core flow path 60. The second fan section 26 is generally radially inboard and downstream of the first fan section 24 such that all flow from the second fan section 26 is communicated into the second stream flow path 58 and the core flow path 60. The fan section 22 may alternatively or additionally include other architectures that, for example, include additional or fewer sections each with or without various combinations of variable or fixed guide vanes.

The first fan section 24 and the second fan section 26 directs airflow into the core flow path 60 such that the core flow stream is further compressed by the high pressure compressor section 28, mixed and burned with fuel in the combustor section 30, then expanded over the turbine sections 32, 34 to rotationally drive the respective high spool 46 and low spool 44 in response to the expansion. The core flow path 60 may alternatively or additionally include other architectures that, for example, include additional or fewer sections and or stages each with or without various combinations of variable or fixed guide vanes.

Downstream of the turbine sections 32, 34, the exhaust duct section 36 may be circular in cross-section as typical of an axis-symmetric augmented low bypass turbofan or may include non-axisymmetric cross-section segments. In addition to the various cross-sections, the exhaust duct section 36 may be non-linear with respect to the central longitudinal engine axis A. Furthermore, in addition to the various cross-sections and the various longitudinal shapes, the exhaust duct section 36 may terminate in the nozzle section 42.

The nozzle section 42 may include a variable exhaust nozzle 62 at the end of the outer case structure 50 that receives flow from the third stream flow path 56, the second stream flow path 58 and the core flow path 60 such as within an embedded engine architecture. It should be understood that various fixed, variable, convergent/divergent, two-dimensional and three-dimensional nozzle systems may be utilized herewith. Alternatively, a variable exhaust nozzle 64 at the end of the intermediate case structure 52 that receives the second flow from the second stream flow path 58 and the core flow path 60 may be provided for a podded engine architecture. Alternatively or in addition thereto, a tailcone 66 may be selectively translated along axis A to further modulate the flow from the second stream flow path 58 and the core flow path 60.

In one disclosed non-limiting embodiment, the intermediate case structure 52 includes a variable area exhaust mixer 70. The variable area exhaust mixer 70 may be located downstream of the of the turbine sections 32, 34 and axially adjacent to the tailcone 66 for control of a flow stream mixture from the third stream flow path 56, the second stream flow path 58 and the core flow path 60. In other words, the variable area exhaust mixer 70 may be axially

located adjacent to an exhaust mixing plane where the core flow path **60** joins the second stream flow path **58**.

The variable area exhaust mixer **70** facilitates variable-cycle engine operations and maintains stall margin requirements through alteration of a fan-to-core area ratio at the exhaust mixing plane in response to desired operating condition. The variable area exhaust mixer **70** further facilitates a desired flow stream mixing to match, for example, engine operating conditions, ambient conditions and mission requirements. The variable area exhaust mixer **70** may be of various styles to include but not be limited to hinging, pivoting, sliding, rotating or other movable structures, to achieve the selective desired mixing of the contributing flow streams.

In one disclosed non-limiting embodiment, the variable area exhaust mixer **70** is an iris-type mechanism with a multiple of flaps **72** (also shown in FIGS. **2** and **3**) that move about a hinge axis **74** at the intermediate case structure **52**. Each flap **72** moves relative to the intermediate case structure **52** at the hinge axis **74** and may at least partially circumferentially overlap when moved between the closed position (see FIG. **1**) and the open position (see FIG. **6**) with continuous variability therebetween (one position shown in FIG. **7**).

In one disclosed non-limiting embodiment, the hinge axis **74** may be axially located aft of the respective flaps **72** and radially outboard of a maximum outer diameter **75** of the tailcone **66**. It should be appreciated that the "hinge axis" mechanism as described herein may include various articulation mechanisms generally located within or at least partially formed by the intermediate case structure **52**. In another disclosed non-limiting embodiment, the flaps **72** move amid struts **73** that extend between the intermediate case structure **52** and the inner case structure **54** (see FIGS. **4** and **5**).

With continued reference to FIG. **1**, when in the closed position, the flaps **72** are aligned with the intermediate case structure **52** to separate the bypass flow stream of the third stream flow path **56** from the mixed flow stream of the second stream flow path **58** and the core flow path **60**. The closed position facilitates full exhaust mixing and cooling for cruise operations. This cruise power setting mode maximizes the backpressure at the exit of the turbine section **34** and increases the pressure ratio of the second fan section **26**. The turbine section **34** power input to the fan sections **24**, **26** is thereby reduced and the backpressure at the exit of the first fan section **24** is minimized. This flow maximization and pressure ratio minimization of the first fan section **24** produces a relatively lower thrust with a relatively higher propulsive efficiency for cruise operations. This cruise power setting mode has a relatively lower turbine inlet temperature versus a maximum power setting mode (see FIG. **6**).

With reference to FIG. **6**, when in the open position, the flaps **72** are articulated to be adjacent to the inner case structure **54**. The open position mixes the flow streams from the second stream flow path **58** and the core flow path **60** into the bypass flow stream in the third stream flow path **56** to facilitate full fan mixing and pressure modulation of the streams.

As the flaps **72** are closed toward the inner case structure **54** (see FIG. **7**) to the maximum power setting mode (see FIG. **6**), the flaps **72** first mix the third flow stream of the third stream flow path **56** with the second flow stream of the second stream flow path **58** and then further mixes the mixed third and second flow streams with the core flow stream **60** of the core flow path **60**. This favors an architecture for the

turbine section **34** that expands to a lower backpressure as consistent with a relatively low specific thrust class engine.

With reference to FIG. **7**, when in an intermediate position, the flaps **72** extend at least partially toward the inner case structure **54**. The intermediate position may be selectively varied to modulate the distribution of the flow stream of the second stream flow path **58** into the respective bypass flow stream of the third stream flow path **56** and the core flow stream of the core flow path **60**. In this disclosed non-limiting embodiment, the flaps **72** may extend adjacent to a wall **55** of the inner case structure **54** that separates the exhaust **76** of the second stream flow path **58** and the exhaust **78** of the core flow path **60**. That is, the core flow stream of the core flow path **60** may be substantially segregated from the mixed flow streams of the second stream flow path **58** and the third stream flow path **56**. Variation of the variable area exhaust mixer **70** can be readily controlled to enhance, for example, the throttle transient response of the engine by modulation of the turbine section **34** power and backpressure to fan sections **24**, **26**.

With reference to FIG. **8**, in another disclosed non-limiting embodiment, the intermediate case structure **52** includes a variable area exhaust mixer **70A** with a multiple of flaps **82** that move relative to a hinge axis **84** formed at the intermediate case structure **52**. In this disclosed non-limiting embodiment, the flaps **82** of the variable area exhaust mixer **70A** may extend further upstream with respect to the tailcone **66** than in the above-disclosed non-limiting embodiment to facilitate mixture control between the flow streams of the third stream flow path **56** and the second stream flow path **58**. That is, the flaps **82** are relatively longer than the flaps **72** such that the flaps **82** achieve an open position adjacent to the intermediate case structure **52** (FIG. **9**).

With reference to FIG. **9**, when in the open position, the variable area exhaust mixer **70A** mixes the third flow stream of the third stream flow path **56** with the second flow stream of the second stream flow path **58**. This mode minimizes the backpressure at the exit of the turbine section **34** and decreases the pressure ratio of the second fan section **26** to increase the power available to drive the first fan section **24**. The turbine section **34** power input to the fan sections **24**, **26** is thereby increased and the backpressure at the exit of the first fan section **24** is maximized. This flow minimization and pressure ratio maximization of the first fan section **24** produces a relatively high specific thrust (engine thrust per lbf per second of engine flow). The total thrust in this high specific thrust mode (see FIG. **9**) is increased by operation of the turbine section **34** at a relatively higher inlet temperature than in cruise mode (see FIG. **8**).

With reference to FIGS. **10-12**, in another disclosed non-limiting embodiment, the intermediate case structure **52** includes a variable area exhaust mixer **70B** with a multiple of flaps **92** that move relative to a hinge axis **94** formed at the intermediate case structure **52**. The variable area exhaust mixer **70B** extends for a relative shorter distance upstream with respect to the tailcone **66** than in the above-disclosed non-limiting embodiments for mixture control between the flow streams from the third stream flow path **56**, the second stream flow path **58** and the core flow path **60**. That is, flaps **92** are relatively shorter than the flaps **72**, **82** and are spaced from the wall **55** of the inner case structure **54** when in an intermediate position (FIG. **11**).

When in the closed position (see FIG. **10**) the flaps **92** are aligned with the intermediate case structure **52** to separate the bypass flow stream of the third stream flow path **56** from

the mixed flow stream of the second stream flow path **58** and the core flow path **60** as described above.

The variable area exhaust mixer **70B** changes the sequence of mixing of the flow streams **56**, **58**, and **60** for the high specific thrust mode. In this disclosed non-limiting embodiment, when articulated between the closed (see FIG. **10**) and open position (see FIG. **12**), the flaps **92** are displaced from the wall **55** of the inner case structure **54** that separates the exhaust **76** of the second stream flow path **58** and the exhaust **78** of the core flow path **60**.

As the flaps **92** close through the intermediate position (see FIG. **11**) to the maximum power setting mode (see FIG. **12**), the flaps **92**, being relatively short, first mix the core flow stream of the core flow path **60** with the second flow stream of the second stream flow path **58** then mixes the mixed second and core flow streams with the third flow stream of the third stream flow path **56**. This favors a turbine section **34** architecture that expands less, i.e., the pressure at the exit of the turbine section **34** is consistent with a relatively high specific thrust class engine that, in this disclosed non-limiting embodiment, is higher than the engine embodiments described above.

When in the intermediate position (one shown FIG. **11**) the flaps **92** are articulated at least partially toward the inner case structure **54** so that a selectively controlled fraction of the second flow stream of the second stream flow path **58** mixes with the flow stream of the third stream flow path with the remainder mixed with the core flow stream of the core flow path **60**. The position of the flaps **92** are controlled to enhance the throttle transient response of the engine by affecting the turbine section **34** power and backpressure to fan sections **24**, **26**.

When included in a three-stream engine, the variable area exhaust mixer provides for variable mixing and cooling between the core flow stream and either or both the mid flow stream and bypass flow stream. The variable area exhaust mixer facilitates the provision of metered, on-demand cooling and mixing to the exhaust flow stream, protects temperature sensitive materials and blocks direct view to the turbine sections. For cruise operations, the Mach numbers in the second flow stream mixing section are relatively low and pressure losses are reduced.

The use of the terms “a” and “an” and “the” and similar references in the context of description (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or specifically contradicted by context. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity). All ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other. It should be appreciated that relative positional terms such as “forward,” “aft,” “upper,” “lower,” “above,” “below,” and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

Although the different non-limiting embodiments have specific illustrated components, the embodiments of this invention are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the other non-limiting embodiments.

It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be understood that although

a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom.

Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present disclosure.

The foregoing description is exemplary rather than defined by the features within. Various non-limiting embodiments are disclosed herein; however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true scope and content.

What is claimed:

1. A gas turbine engine, comprising:
 - an outer case structure around a central longitudinal engine axis;
 - an intermediate case structure inboard of the outer case structure;
 - an inner case structure inboard of the intermediate case structure; and
 - a variable area exhaust mixer movable between a closed position adjacent to the intermediate case structure and an open position adjacent to the inner case structure at a position radially inward of a first stream flow path defining a core flowpath, the variable area exhaust mixer including a hinge axis radially outboard of a maximum outer diameter of a tailcone, the hinge axis axially aft of a multiple of respective flaps;
- wherein the multiple of respective flaps are operable to extend toward a wall in the inner case structure when between the closed position and the open position; and wherein the wall separates an exhaust of a second stream flow path and an exhaust of the core flow path.
2. The gas turbine engine as recited in claim 1, wherein the variable area exhaust mixer is downstream of a turbine section.
3. The gas turbine engine as recited in claim 1, wherein the multiple of respective flaps open radially inward toward the inner case structure.
4. The gas turbine engine as recited in claim 1, wherein the multiple of respective flaps are operable to extend to the wall to segregate the second stream flow path and the core flow path.
5. The gas turbine engine as recited in claim 1, wherein the variable area exhaust mixer is upstream of the tailcone.
6. The gas turbine engine as recited in claim 1, wherein the variable area exhaust mixer is upstream of a nozzle section.
7. The gas turbine engine as recited in claim 6, wherein the nozzle section includes a convergent/divergent nozzle.
8. A gas turbine engine, comprising:
 - a third stream flow path;
 - a second stream flow path inboard of the third stream flow path;
 - a first stream flow path defining a core flow path, the core flow path inboard of the second stream flow path; and
 - a variable area exhaust mixer operable to control flow between the third stream flow path, the second stream flow path and the core flow path, the variable area exhaust mixer including a hinge axis radially outboard of a maximum outer diameter of a tailcone, wherein the

variable area exhaust mixer is downstream of a turbine section and the hinge axis is axially aft of a multiple of respective flaps,

wherein in an open position the variable area exhaust mixer mixes a bypass flow stream, a second flow stream, and a core flow stream from the third stream flow path, second stream flow path, and core flow path, respectively, into the bypass flow stream. 5

9. The gas turbine engine as recited in claim 8, wherein the variable area exhaust mixer is operable to segregate the core flow path in a position between a closed position and the open position. 10

10. The gas turbine engine as recited in claim 8, wherein the variable area exhaust mixer is operable to selectively mix the core flow stream from the core flow path with the bypass flow stream from the third stream flow path and the second flow stream from the second stream flow path. 15

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